MITSUBISHI POWER

THREE TECHNOLOGIES TO WATCH

IN THE NEXT PHASE OF THE ENERGY TRANSITION

MOVE THE WORLD FORWARD

MITSUBISHI HEAVY INDUSTRIES GROUP

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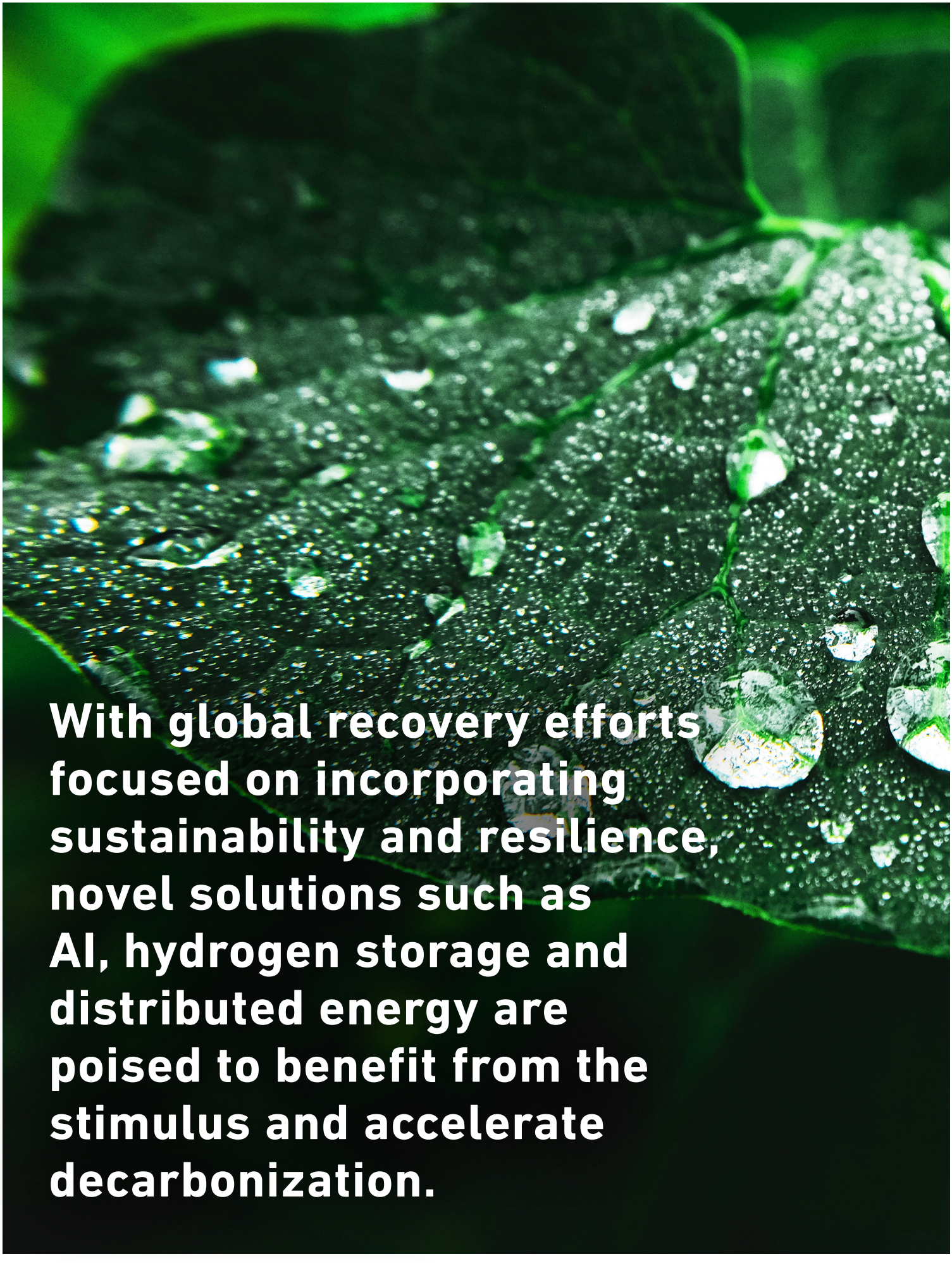
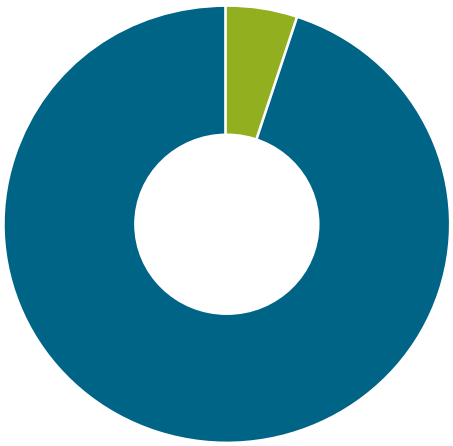

With global recovery efforts focused on incorporating sustainability and resilience, novel solutions such as AI, hydrogen storage and distributed energy are poised to benefit from the stimulus and accelerate decarbonization.

INTRODUCTION

AS COUNTRIES AROUND THE WORLD COMMIT TRILLIONS TO SPUR AN ECONOMIC RECOVERY IN THE WAKE OF COVID-19, ONE COMMON THEME IS TO SEIZE WHAT MANY CONSIDER AN UNPRECEDENTED OPPORTUNITY. AS THE WORLD ECONOMIC FORUM AND OTHERS ARGUE, IT'S AN OPPORTUNITY TO BUILD SUSTAINABILITY INTO THE RECOVERY.

For the energy transition, this could be a transformative moment, a time to leapfrog previous obstacles and advance technologies vital to achieving a low-emissions future and the ultimate goal of net zero.

Outside of Europe, however, governments, have more work to do. Of the $12 trillion dedicated for stimulus packages worldwide, $583 million – less than 5 percent – is earmarked for green initiatives. With the global population projected to add another 2.2 billion people by 2064, approaching nearly 10 billion, energy demand is expected to increase as well, ratcheting up the urgency to decarbonize the sector. The U.S. Energy Information Administration estimates that global energy usage will increase nearly 50 percent between 2018 and 2050.



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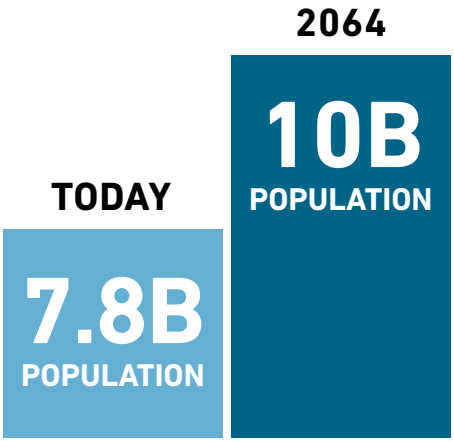

INCREASED ENERGY DEMAND IS EXPECTED

AS THE GLOBAL POPULATION GROWS, INCREASING THE NEED FOR DECARBONIZED SOLUTIONS.

"There are two important factors to think about for the future of energy," says Taiji Yoshida, chief strategy officer at Mitsubishi Power, based in Yokohama, Japan. "One is sustainability, which means we are thinking about the next generation, about children, about grandchildren. We look to create the circular society, where nothing is wasted. The other factor is diversified energy – the best way of using energy is a mixture."

Economies, geographies, current infrastructure and energy needs differ from one place to the next, after all. Rather than a single solution, a diverse range of technologies must be available. Public and private investments are needed to create new breakthroughs, to be sure. But equally important is leveraging the progress being made right now.

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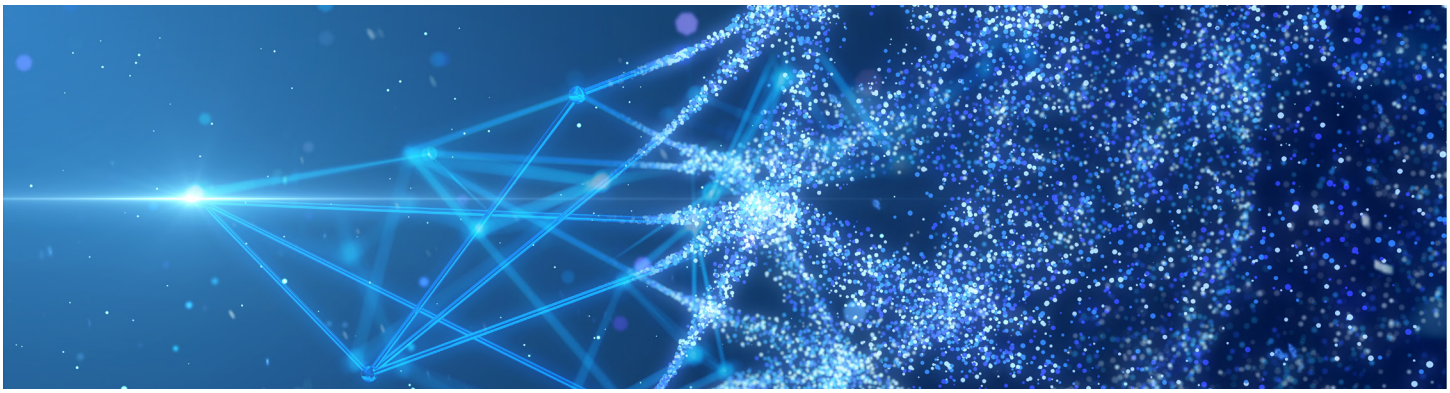
– Taiji Yoshida, chief strategy officer, Mitsubishi Power

Dispersed across the globe, from a bay in southern Japan to the salt flats of the Western United States to the deserts of North Africa, novel energy technologies are already in place or in the works that point the way to decarbonization. They strike the all-important balance between availability, reliability, affordability and environmental impact.



#1
AI-DRIVEN DECISION-MAKING

THE POWER PLANT OF THE FUTURE will have a voice – and it will have answers, lots of answers about how the plant is performing at any given moment. The control operator simply has to ask: *What is the compressor efficiency of gas turbine No. 1? What's the steam pressure of system No. 2? What are the bearing vibration levels of system No. 3?*

No need to dig through dense manuals or search through a labyrinth of online systems. In an instant, the plant tells the operator what he or she wants to know so they can act on real-time information.

Just as previous innovations – think solar power, digitization and the like – transformed energy, artificial intelligence is expected to have a profound effect. By analyzing the growing data produced throughout a plant, AI will tame the complexity: It will optimize operations and maintenance and deliver new insights that improve decision-making about power generation and even the business itself on the path to decarbonization.

But first, says Marco Sanchez, vice president and head of intelligent solutions at Mitsubishi Power, the technology must overcome skepticism – the fear that AI will replace humans. On the contrary, the solutions that his team are developing are designed to assist humans, to equip them to do more. Take TOMONI Voice, Mitsubishi Power's Alexa-like voice platform that was announced to customers in August. The first installation is scheduled for next summer.

"The platform provides quicker access to critical information," Sanchez says, "and not just for electrical engineers. It uses AI to translate very complex technical data so that non-engineers can understand what's happening at the plant."

Fifty miles west of Kobe, Japan, nestled on the coast of the Seto Inland Sea, the world's first autonomous power plant is taking shape. T-Point 2 is a combined-cycle power plant at Mitsubishi Power's Takasago Machinery Works facility. Since 1997, the company has used the site to demonstrate and validate its latest gas turbines and other new technologies under actual operating conditions, dispatching power to the local grid. Today, the team at T-Point 2 is validating the next JAC model, a gas turbine with an air-cooled combustor, as well as the "building blocks" to an autonomous power system, says Sanchez.

In addition to streamlining access to essential data, the TOMONI AI tools will provide data that wasn't previously available, such as real-time degradation of a plant's numerous auxiliary systems. Each system has a corresponding degradation curve, an estimate of its wear and tear based on time and usage. With AI, an operator will be able to look at current degradation data gathered from sensors, and then tune the power generation accordingly.

"Today, our users [utilities and independent power producers] are selling power by the minute," says Sanchez, "but they can't measure performance by the minute."

Through an AI simulation, plant operators will be able to identify weak links, auxiliary systems that cause up to 25 percent of "trips," or unexpected shutdowns, he says. Operators will also be able to avoid unnecessary scheduled shutdowns for maintenance. AI will indicate when maintenance or a replacement is actually needed.

This represents a significant shift: from an OEM's predetermined schedules to the actual condition of components and auxiliary systems according to real-time data from thousands of RFID tags and sensors. Such precision could extend the maintenance schedule and life span of these systems. Using TOMONI AI tools and advanced computing to provide more accurate system warranties and reliability guarantees, Mitsubishi Power would assume the risk of a potential failure instead of a customer.

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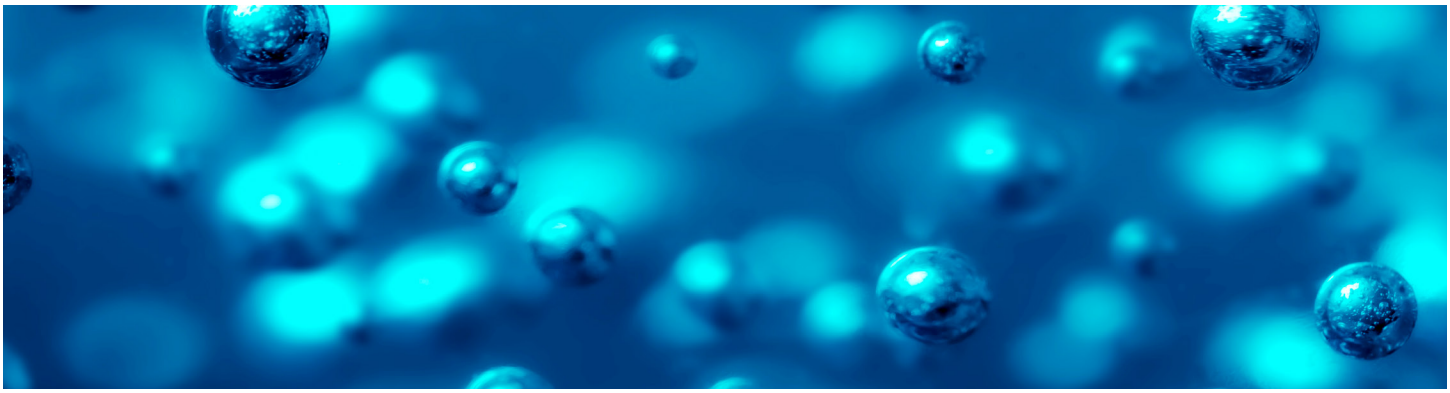
TOMONI's core development leverages simulation to validate the accuracy and viability of its innovations. Eventually, high fidelity simulators will go a step further, connecting all this operational data to financial models in what Sanchez describes as "the ultimate advancement – synchronization of a high-fidelity simulator reality."

Translation: AI that helps the staff make operational decisions based on impact to the business. It's AI that improves the bottom line.



#2
HYDROGEN STORAGE AT SCALE

HYDROGEN HAS LONG BEEN TOUTED as a key ingredient of the energy transition. As recently as the early 2000s, the much-discussed "hydrogen economy" seemed on the verge of emerging. "The value was there," says Mike Ducker, vice president of renewable fuels and Western region (U.S.) at Mitsubishi Power. "The market need had just not materialized yet." That was then. Today, Ducker says he's fully convinced those market needs have now materialized. And he's joined by a wave of peers who have changed their thinking in the last few years.

The industry's shift is a reflection of the latest "market signals," he says, beginning with policy changes that support more ambitious decarbonization goals set by one state, country or region after another. The goals have spurred increasing amounts of variable renewable energy to meet these targets, such as larger wind and solar installations, which create the need for larger and longer-term storage solutions.

Enter hydrogen. In fact, the first example of utility-scale hydrogen storage is now underway. In partnership with Magnum Development, Mitsubishi Power is developing the Advanced Clean Energy Storage project in Delta, Utah, outside of Salt Lake City. The innovative, $1 billion facility will sit above a geologic formation that makes the world's largest storage of hydrogen-based clean energy possible: a salt dome 3,000 feet underground. Within that dome, engineers are creating massive salt caverns in which 150,000 megawatt hours of green hydrogen energy (that is, hydrogen produced from renewables) will be stored.

The operation is designed to function like an enormous long-term battery, storing hydrogen for weeks or even months. When power is needed, the hydrogen will run

hydrogen-fired turbines, supplying clean energy to the Western U.S., or even help to decarbonize other sectors, such as transportation. A separate project in Delta will contribute to this as well. The adjacent Intermountain Power Plant is scheduled to retire its coal units in 2025 and replace them with Mitsubishi Power's JAC gas turbines. The units will operate on a mix of natural gas and hydrogen before converting to hydrogen only by 2045, which would make them the industry's first such turbines.

Petrochemical companies on the Gulf Coast have used underground salt caverns for hydrogen storage for years. What's innovative about the new facility in Utah, says Ducker, "is how we're applying these technologies to the changing market needs. It's elegant in its simplicity."

The scale is also new. It will provide utilities with a practical demonstration of the technology, rather than smaller pilot projects, and equally important, it'll give utilities a compelling financial model. By working out the manufacturing efficiencies and driving down costs through economies of scale, the facility can serve as "a great launchpad" for other projects or for other industries, says Ducker.

Today, hydrogen storage is poised to follow the trajectory of solar power. In the U.S., it also began out West, where the market signals were compelling, especially in the early 2000s. Two decades later, solar installations have become ubiquitous throughout the country, producing an estimated 62.5 gigawatts of power.

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– Mike Ducker, vice president of renewable fuels and Western region (U.S.), Mitsubishi Power

Over the next five to 10 years, Ducker expects that hydrogen development in the U.S. and elsewhere will continue to grow and that new storage options will emerge. "You'll hear 'Now, because the markets' needs for energy storage have increased and costs have continued to come down, hydrogen further helps to solve my decarbonization goals,'" he says.

#3
DISTRIBUTED POWER TO THE PEOPLE

AS MORE COUNTRIES PRIORITIZE the UN's Sustainable Development Goals, improving access to affordable, reliable and cleaner power is vital. Today, an estimated 850 million people live without adequate electricity, predominately in developing countries. Their populations are growing rapidly, creating more demand, and the ability to power schools, homes and businesses for an emerging middle class can unlock economic progress.

Rural towns in Algeria in northern Africa are typical of such communities. Living amid sand dunes in the Sahara Desert, the 500,000 or so residents rely on a regional power grid prone to outages, which disrupt daily life and local economies, underscoring the sense of isolation. To address the infrastructure's shortcomings, the Algerian government has added aero-derivative gas turbine generation that augments the existing distributed power generation model. The mobile units, made by PW Power Systems, a group company of Mitsubishi Power, provide greater reliability and flexibility. They're capable of quickly delivering 30 megawatts of electricity, offer high thermal efficiency and produce much lower emissions than older turbines and reciprocating engines.

In developed countries, the on-demand capability of aero-derivative turbines makes them an ideal solution for the intermittent supply problems caused by the expanded use of renewables on the grid. But in developing countries, the units support more conventional equipment to keep the lights on.

Multi-unit load sharing further extends the turbines' flexibility and capability in the Adrar province of southwestern Algeria. Several FT8 MOBILEPAC units, PW Power Systems' gas turbine package designed to provide movable power, were connected, creating a coordinated distributed

generation system for an area the size of California. Through this technique, the company spreads the generation evenly among the turbines, keeping them online rather than using some units fully and shutting down others. This enables them to respond immediately to support the grid. "The units monitor a variety of parameters on the system and react automatically to sudden changes in demand or supply," says Stefan Zavatone, vice president of marketing and communications for PW Power Systems, based in Glastonbury, Connecticut.

Historically, Adrar's residents experienced several power outages a year, but in the two years since PW Power Systems implemented this solution, they have not suffered a single blackout.

The mobility of aero-derivative units is important in environments where power needs are dynamic. The self-contained packages are very compact and lightweight, allowing operators to move them easily by land, sea or air to meet changing demand. In Algeria, where the government operates 54 PW Power Systems mobile units throughout the country, more than 450 megawatts of power have been relocated to address shifting needs and to expand the service area to 18 sites from the initial 12 – a 50 percent increase.

In the coming years, the aero-derivative gas turbine will continue serving as a bridge to decarbonization. PW Power Systems is developing the capability to operate their units on hydrogen fuel, which would further reduce carbon emissions. "If you convert excess electricity from renewables into storable hydrogen, and then burn it in a gas turbine when you need the extra power, you have on-demand zero carbon electricity," says Zavatone.

In the coming years, the aero-derivative gas turbine will continue serving as a bridge to decarbonization.

Another distributed clean energy solution that promises to be impactful is the solid oxide fuel cell (SOFC). "Not many people know the technology of [SOFC] right now," says Yoshida, Mitsubishi Power's CSO. "But it's one of the best technologies for a sustainable circular society."

Rather than burning fuel, SOFC generates electricity through a chemical reaction, the oxidation of a fuel. The technology can generate electricity from a diverse range of fuels, from natural gas to hydrogen, and its efficiency is among the highest of any power solution. Because its rotating parts move so quietly, the fuel cell eliminates another emission: noise. Unlike power generation that requires a sound buffer, it will offer more flexibility as a small, silent source of carbon-free power.

REACHING THE DESTINATION: NET ZERO.

As the economic recovery takes shape, the degree to which sustainability is interwoven in stimulus spending and policies will determine just how much the energy transition will benefit from this opportunity.

If it proves to be a transformative moment, AI, hydrogen storage and distributed energy will no doubt play a leading role. They'll illustrate the multiple paths that the energy industry needs to take toward a shared destination – a net zero future.

Just as important, these technologies will demonstrate the diligence and ingenuity we need to get there as a society.

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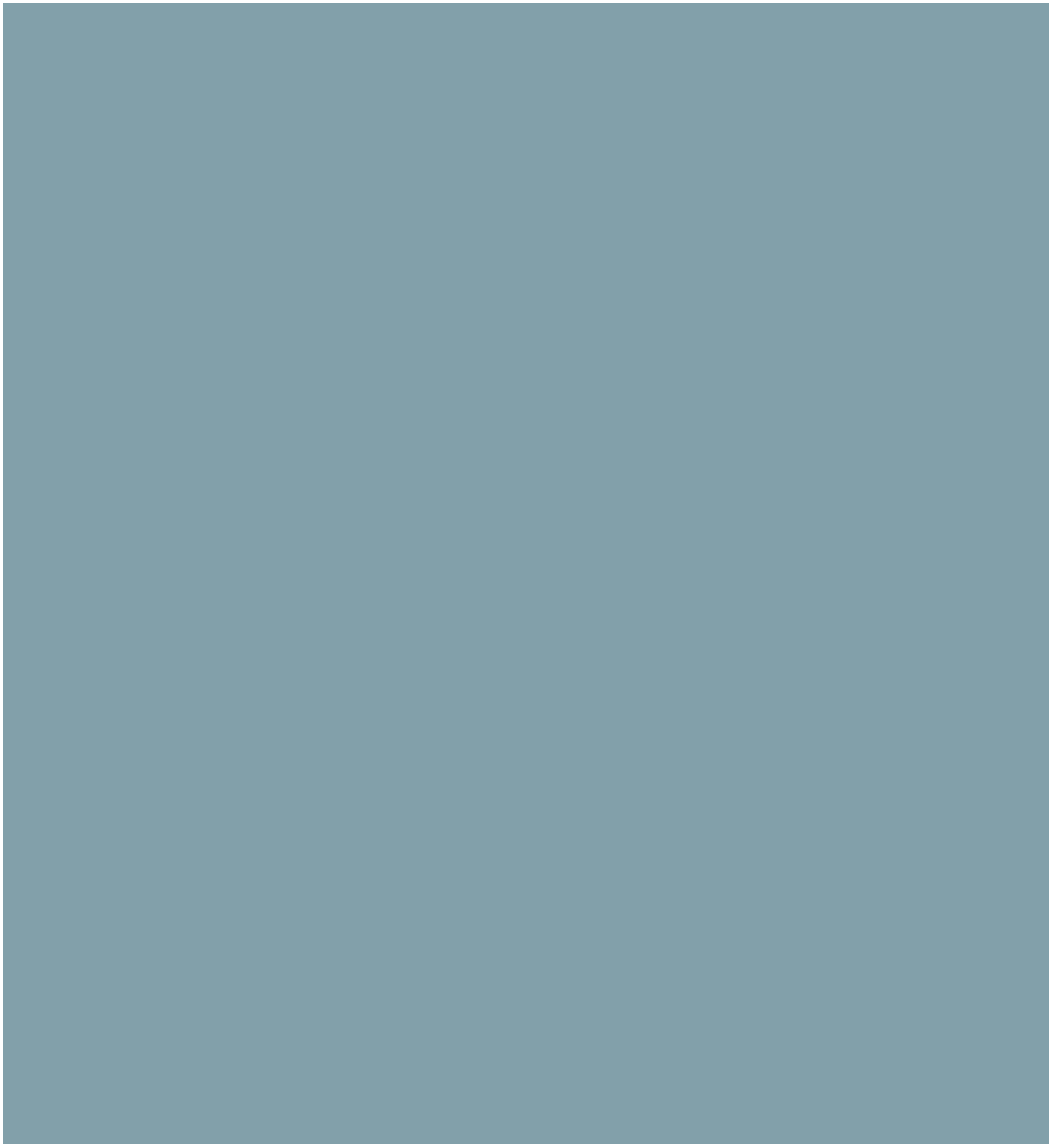

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